Short Narrative Review
Acta Medica Academica 2023;52(2):148-151
DOI: 10.5644/ama2006-124.416

Intra-renal Arteries in Nephrectomy from a Historical Aspect, a Quest Originated by Medical Illustrations to Reach Modern Angiography

Vassiliki Kyriakou, Georgia Chondrou, Panagiotis Georgakopoulos, Evaggelos Mavrommatis

Medical School, National and Kapodistrian University of Athens, Athens, Greece

Correspondence: *evagmavrommatis@protonmail.com*; Tel.: + 30 697 6778252

Received: 4 April 2023; **Accepted:** 7 June 2023

Abstract
The aim of the present paper is to contribute to the understanding of the history of the anatomical study of the intra-renal arteries. The vasculature and especially the intra-renal arteries of the kidneys are an intriguing field which was first studied through art and then perfected by medicine. Angiography and microsurgery have resulted in partial nephrectomy techniques for surviving kidneys with adequate functional results. Graves' categorization dating from 1954 opened the way for innovative approaches that have resulted in modern topographical anatomy. **Conclusion:** Our understanding of the anatomy of intra-renal arteries has played a significant role in surgical anatomy and internal medicine.

Key Words: Graves' Categorization ▪ Kidneys ▪ Intra-renal Arteries ▪ Nephrectomy ▪ Angiography.

Introduction

The segmental anatomy of the kidneys is a challenging issue due to the wide range of endo- or intra-renal vessel variations (1). Many scholars have tried to provide a concise system that is accepted throughout the world. The embryological development of the kidney, the topographic anatomy of the organ, the renal pyramids, and the anatomy of the segmental kidney arteries have been all used as the basis of different approaches to topographical anatomy. Nevertheless, a global consensus is fundamental since kidneys play a crucial role in surgical procedures. A cluster of dangerous situations and possible fatalities may occur, such as necrosis, during nephrectomies and alter the expected results.

The kidneys, like the lungs, liver and spleen, have a system of segmental arteries with an essential role in the surgical anatomy of these organs (Figure1). Regarding the intra-renal arteries, their study began using a scientific surgical approach during the last seven decades, even though efforts began in the 17th century. Despite the fact that the

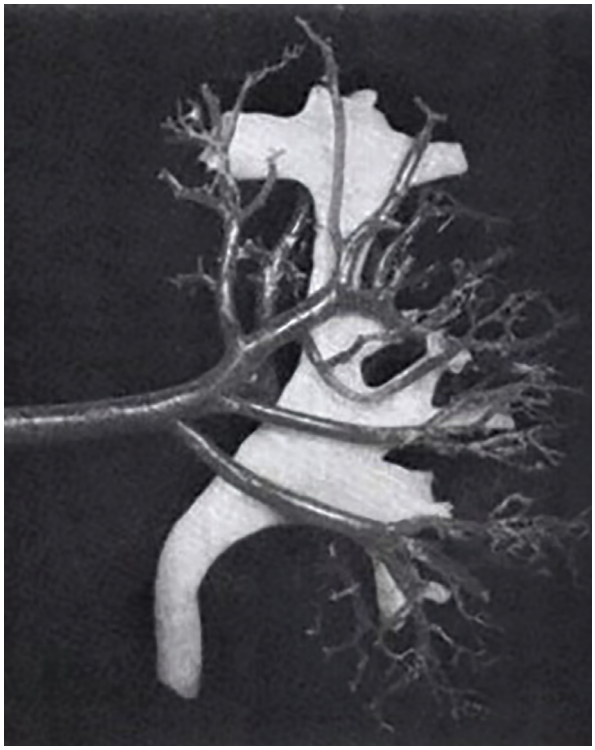

Figure 1. A figure of human kidney's blood supply and collecting system (2).

first detailed work began at the beginning of the 20th century, it is surprising that the best descriptive attempt was not provided by a physician or anatomist, but by a medical artist.

This historical vignette aims to record the story of the decade from 1950 to 1960, when it all started.

The Painter

The German artist Max Brödel (1870-1941), who was born in Leipzig, was to become one of the greatest medical illustrators of modern times (3). He graduated from the Leipzig Academy of Fine Arts, and at a young age was brought to the John Hopkins School of Medicine to work as an illustrator for the medical authorities of the school. Brödel was credited with the development of the carbon dust technique for medical and scientific illustrations. His innovative thought, to present his illustrations in an acceptable medium that was able to demonstrate the vividness and the detailed characteristics of living tissues, paved the way for a second breakthrough in art, using clay-surfaced lithographic transfer paper (4). Those two novelties created a new era in topographical anatomy. He soon became known as an anatomist and scientist, mainly for his description of the avascular area of the kidney (which became known as Brödel's bloodless line) (Figure 2) (5) and an improved method of nephropexy using a suture that he designed (Brödel's suture) (6). His description of the vascular system of the kidneys was the best at that time (7).

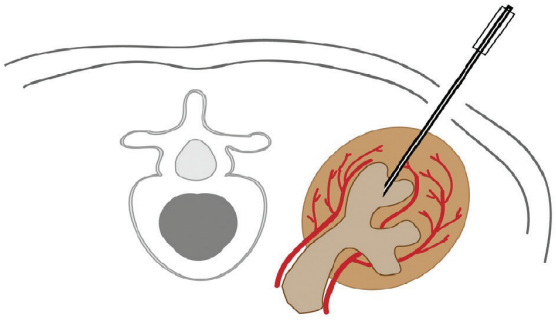

Figure 2. Brödel kidney avascular line (5).

The Pioneer

It was F.T. Graves who presented a study on the intra-renal arteries for the first time back in 1954, which has remained in use until today (8). This gold standard approach to the anatomical study of the segmental renal arteries led to the categorization of vascular renal segments which is of great value for nephrectomies. Graves, who was a prolific researcher into the vascularization of the kidneys gave us a proposal of five vascular segments: i) the apical/superior, the upper pole in both the anterior and posterior planes, ii) the upper, central area, iii) the middle, the area between the upper and the lower pole, iv) the lower/inferior, forming the lower pole in both the anterior and posterior planes, and v) the posterior, the area between the apical and the lower pole in the posterior plane.

The intra-renal arteries are known for their diversity. However, Graves recorded what in his opinion should be followed as the "normal" pattern. Thus, according to his survey, the renal artery splits into anterior and posterior branches before the hilum. The anterior branch is divided into four segmental branches which provide blood to the apical/superior, upper, middle, and inferior segments of the kidney. The posterior branch provides blood to the posterior segment of the kidney. Furthermore, each branch supplies blood to a lobar artery, which in its turn provides hematosis to the renal pyramid. Each lobar artery is further separated into two or three more inter-lobar arteries, which arch over the base of the pyramid in order to form the various arcuate arteries. From every arcuate artery various interlobular arteries originate, and their branches constitute the glomerular capillaries which are the fundamental factors for the essential action of the kidneys, that is, filtration. We must have in mind that every segmental renal artery should be considered as the end.

Graves' studies distinguished further variations of each segmental artery. That is: a) for the apical segmental artery he recognized four types: i) Type I, arising from the upper segmental artery, ii) Type II, arising from the junction between the anterior and posterior division of the main stem

renal artery, iii) Type III, arising at the junction of the main renal artery with the aorta, entering the apical segment outside the hilum and iv) Type IV, arising from the posterior division; b) for the upper, middle and lower segmental arteries he recognized three groups: i) Group I: the lower segmental artery arises first, while the upper and middle have a common origin, ii) Group II: the upper segmental artery arises first, while the middle and lower have a common origin and iii) Group III: the upper, middle and lower segmental arteries arise in common (9-14).

The Reformer

A few years after Graves' categorization, it was Boijsen who, with the use of radiology, presented an angiographic study of the renal arteries. His differentiated approach in the segmental anatomy of the kidneys sought to ameliorate or supplement Graves' efforts. Boijsen had the belief that the segmental arteries did not correspond to the kidney's parenchyma division according to the topographical view. He based this on the fact that an average adult kidney has seven pairs of Ventral-Dorsal pyramids. Therefore, he introduced the idea of dividing the kidneys into four segments based on the relationship of the segmental arteries to the renal pyramids. That is: i) Segment I containing Pyramids 1-2 Ventral and Dorsal, ii) Segment II containing Pyramids 6-7 Ventral and Dorsal, iii) Segment III containing Pyramids 3-5 Ventral, and iv) Segment IV containing Pyramids 3-5 Dorsal (15).

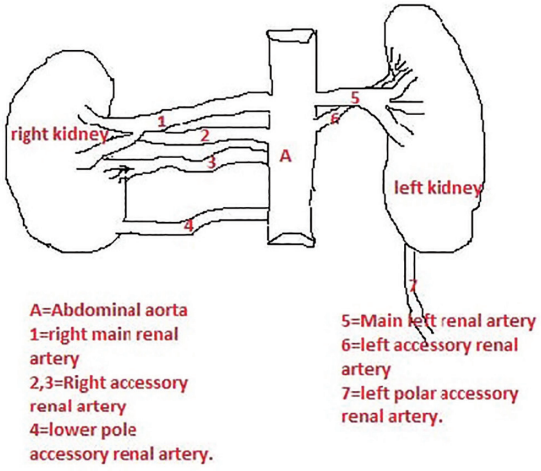

Figure 3. Vascular variations of Kidney (16).

Discussion

Recent studies have demonstrated that in the human kidneys the arterial vasculature is frequently different from the description made by Graves 65 years ago (Figure 3) (16). Additionally, in a significant percentage of cases, a single renal segment receives two or more branches which originate from another artery leading to a different segment. Thus, in 47% of cases the arteries may derive from a common trunk. This fact should be taken into account by surgeons when performing nephrectomies (17-18). With the evolution of microsurgery and the tendency towards the saving of organ tissues rather than complete resection, partial nephrectomy is gaining more interest in oncological kidney surgery, and in polytraumatic patients. Kidney microsurgery requires mapping and a good knowledge of the vascular intra-renal anatomy for acceptable outcomes both oncologically and functionally (17-19). Thus, nephrectomy requires imaging, nephrometry scoring systems, and vascular control techniques so that the surgeon is able to maximize the remaining vascularized parenchyma, control renal function and minimize local ischemia (20). In 1998, the Terminologia Anatomica consensus homologated two branches of the renal artery: i) the anterior, and ii) posterior, while five segmental branches were recognized: i) four from the anterior branch and ii) one from the posterior branch. This partially altered Graves' categorization after almost 70 years of global acceptance (19). The modern practice of thorough presurgery mapping of the renal arterial net is the outcome of the diachronic anatomical investigation which is highlighted in this essay.

Epilogue

Max Brödel introduced the idea of describing the small arteries and became known for his work in renal anatomy. Graves presented his approach to

the intra-renal vasculature, which after some reforms is still in use and mentioned by studies in the field. Partial nephrectomy is the modern form of kidney surgery and knowledge of the blood supply is a key element for success.

What Is Already Known on This Topic:
A modern anatomical study on intra-renal arteries and its role in surgical anatomy.

What This Study Adds:
This study, with its starting point in the work of a painter, describes the diachronic development of the medical-anatomical study of the intra-renal arteries, and how modern medicine, with modern methods such as angiography, can help the physicians to understand their topographical anatomy in order to apply it in the surgical field.

Authors' Contributions: Concept: VK and GC; Design: VK and GC; Literature search: VK, GC and PG; Data analysis: PG; Manuscript preparation: VK, GC and PG; Manuscript editing and manuscript review: EM. The final version of the manuscript has been read and approved by all the authors.

Conflict of Interest: The authors declare that they have no conflict of interest

References

1. Vordermark JS 2nd. Segmental anatomy of the kidney. Urology. 1981;17(6):521-31. doi: 10.1016/0090-4295(81)90067-4.
2. Sampaio FJ, Aragao AH. Anatomical relationship between the intrarenal arteries and the kidney collecting system. J Urol. 1990;143(4):679-81. doi: 10.1016/s0022-5347(17)40056-5.
3. Treadgold S. Max Bordel; 1870-1941 [in French]. Med Biol Illus. 1958;8(4):202-9.
4. Wolff M, Radwan H. Max Brödel (1870-1941): his life and contribution to the development of modern surgery [in German]. Chirurg. 1997 Aug;68(8):840-7. doi: 10.1007/s001040050283.
5. Radiopaedia a rapidly growing peer-reviewed open-edit educational radiology resource. Bashir O, Avascular plane of Brodel (diagram). Case study, https://doi.org/10.53347/rID-17859. [Cited 2023 Apr 4]. Available from: https://radiopaedia.org/cases/avascular-plane-of-brodel-diagram.
6. Schultheiss D, Engel RM, Crosby RW, Lees GP, Truss MC, Jonas U. Max Brödel (1870-1941) and medical illustration in urology. J Urol. 2000;164(4):1137-42.
7. Brödel M.: The intrinsic blood vessels of the kidney and their significance in nephrotomy. Bull. Johns Hopk. Hosp. 1900(12):251-60.
8. Graves FT. The anatomy of the intrarenal arteries and its application to segmental resection of the kidney. Br J Surg. 1954;42(172):132-9. doi: 10.1002/bjs.18004217204.
9. Graves FT. The anatomy of the intrarenal arteries in health and disease. Br J Surg. 1956;43(182):605-16. doi: 10.1002/bjs.18004318213.
10. Graves FT. The aberrant renal artery. J Anat. 1956;90(4):553-8.
11. Graves FT. The aberrant renal artery. Proc R Soc Med. 1957;50(5):368-70.
12. Graves FT. Renal hypothermia: an aid to partial nepnrectomy. Br J Surg. 1963;50:362-7. doi: 10.1002/bjs.18005022203.
13. Graves FT. Renal hypothermia: an aid to partial nepnrectomy. Br J Surg. 1963;50:362-7. doi: 10.1002/bjs.18005022203.
14. Graves FT. An experimental study of the anatomy of the tubules of the human kidney and its relation to calculus formation. Br J Urol. 1982;54(6):569-74. doi: 10.1111/j.1464-410x.1982.tb13598.x.
15. Boijsen E. Angiographic studies of the anatomy of single and multiple renal arteries. Acta Radiol Suppl. 1959;183:1-135.
16. Deka D, Nidhi A, Yadav N. Variations in vasculatures of kidney – A case. Int J Anat Var. 2021;14(4):84-5.
17. Macchi V, Crestani A, Porzionato A, Sfriso MM, Morra A, Rossanese M, et al. Anatomical study of renal arterial vasculature and its potential impact on partial nephrectomy. BJU Int. 2017;120(1):83-91.
18. Dăescu E, Zăhoi DE, Motoc A, Alexa A, Baderca F, Enache A. Morphological variability of the renal artery branching pattern: a brief review and an anatomical study. Rom J Morphol Embryol. 2012;53(2):287-91.
19. Bouzouita A, Saadi A, Hermi A, Chakroun M, Bouchiba N, Allouche M, et al. Cadaveric study of arterial renal anatomy and its surgical implications in partial nephrectomy. Surg Radiol Anat. 2021;43(9):1449-59.
20. Klatte T, Ficarra V, Gratzke C, Kaouk J, Kutikov A, Macchi V, et al. A Literature Review of Renal Surgical Anatomy and Surgical Strategies for Partial Nephrectomy. Eur Urol. 2015;68(6):980-92.